Enhancing the Model-Based Definition with Manufacturing Information through Linked Data for Design Exploration

DMDII/NIST MBE Summit 2016
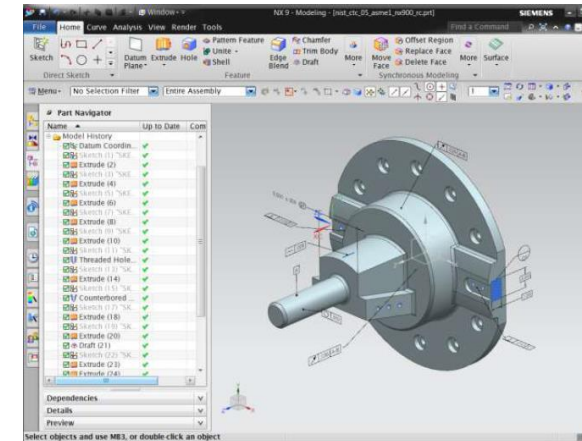**Gaithersburg, MD**

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Siemens Corporation, Corporate Technology

Siemens Corporate Technology

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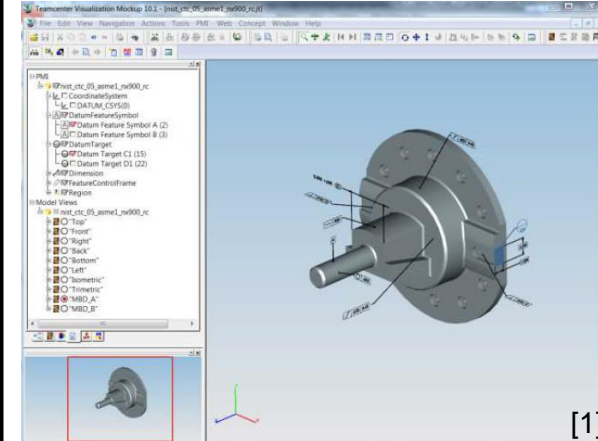
What problems are we addressing?

MBD approach is currently one-way

- Communicate design intent to manufacturing
  - Manufacture in-house or procure from supplier
- Focus is on annotating 3D geometry with PMI
  - GD&T, surface finish, materials, etc.
- Design and Manufacturing still independent
  - Re-work is lengthy process and costly
- Design stage does not fully leverage manufacturing process information
- Design traceability is difficult

3D CAD Model with PMI
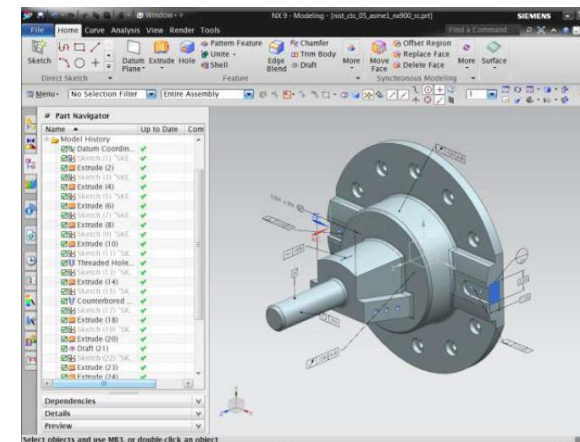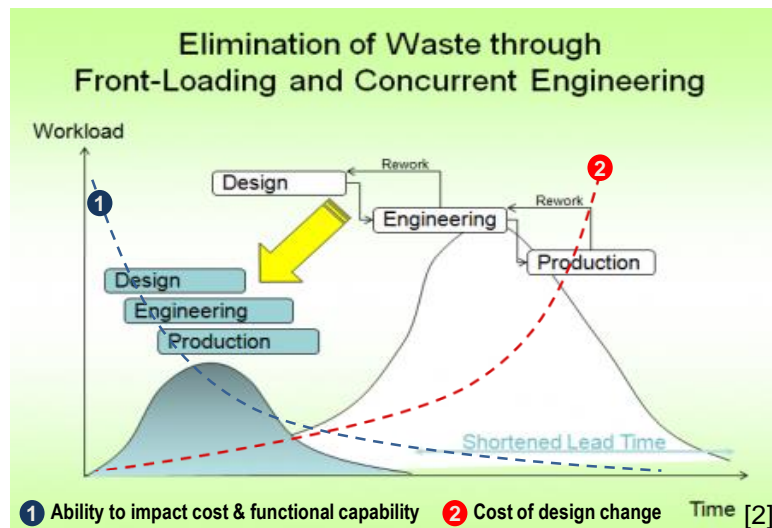
STEP/JT accompanied by 2D drawing
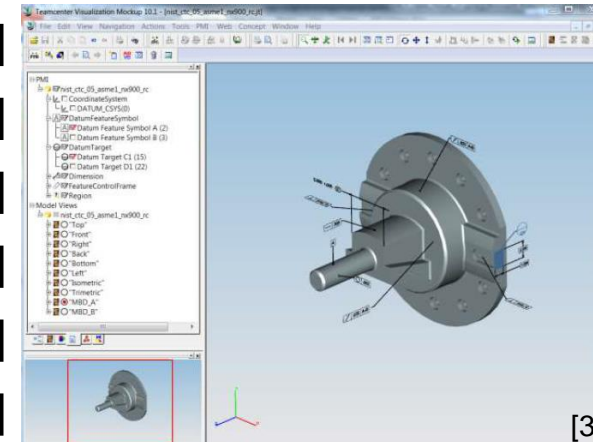
Design

Manufacturing

[1]

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Opportunity: Move Manufacturing Left via MBD

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Extend MBD with mfg. process information

- Enable concurrent engineering
  - Consider manufacturing processes in earlier design stages
- Simultaneously consider functional characteristics, manufacturability, manufacturing costs
- In-house as well as supplier scenarios

Elimination of Waste through Front-Loading and Concurrent Engineering

① Ability to impact cost & functional capability   ② Cost of design change   [2]

3D CAD Model with PMI

STEP/JT accompanied by 2D drawing   [3]

Design → **Manufacturing**

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Project Concept

Methodology: Extend MBD with mfg. process info; Create a digital web of linked design/mfg. data, analysis tools, and DSE framework
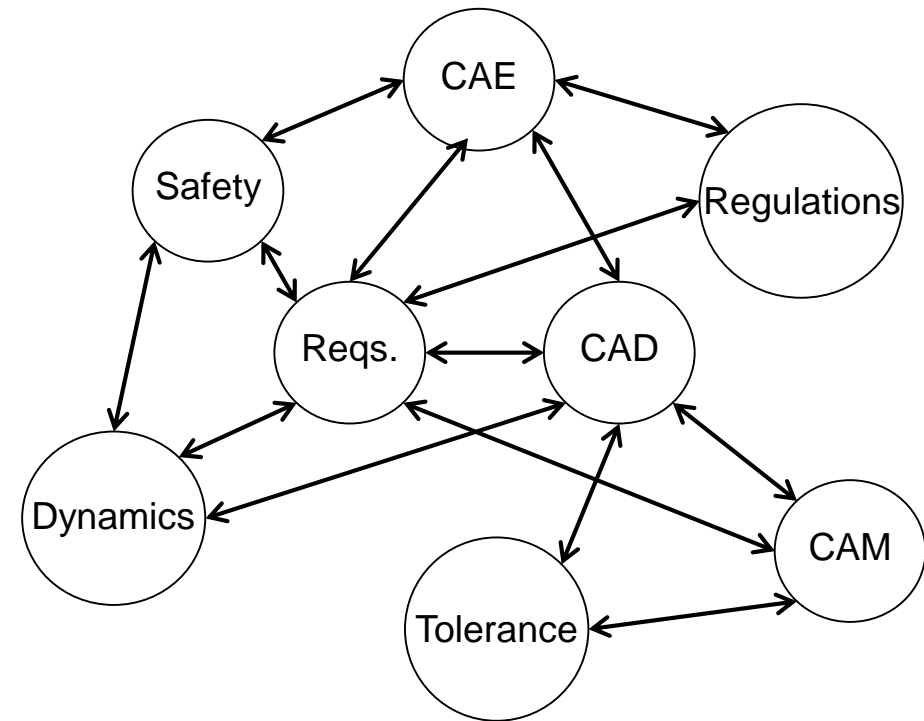

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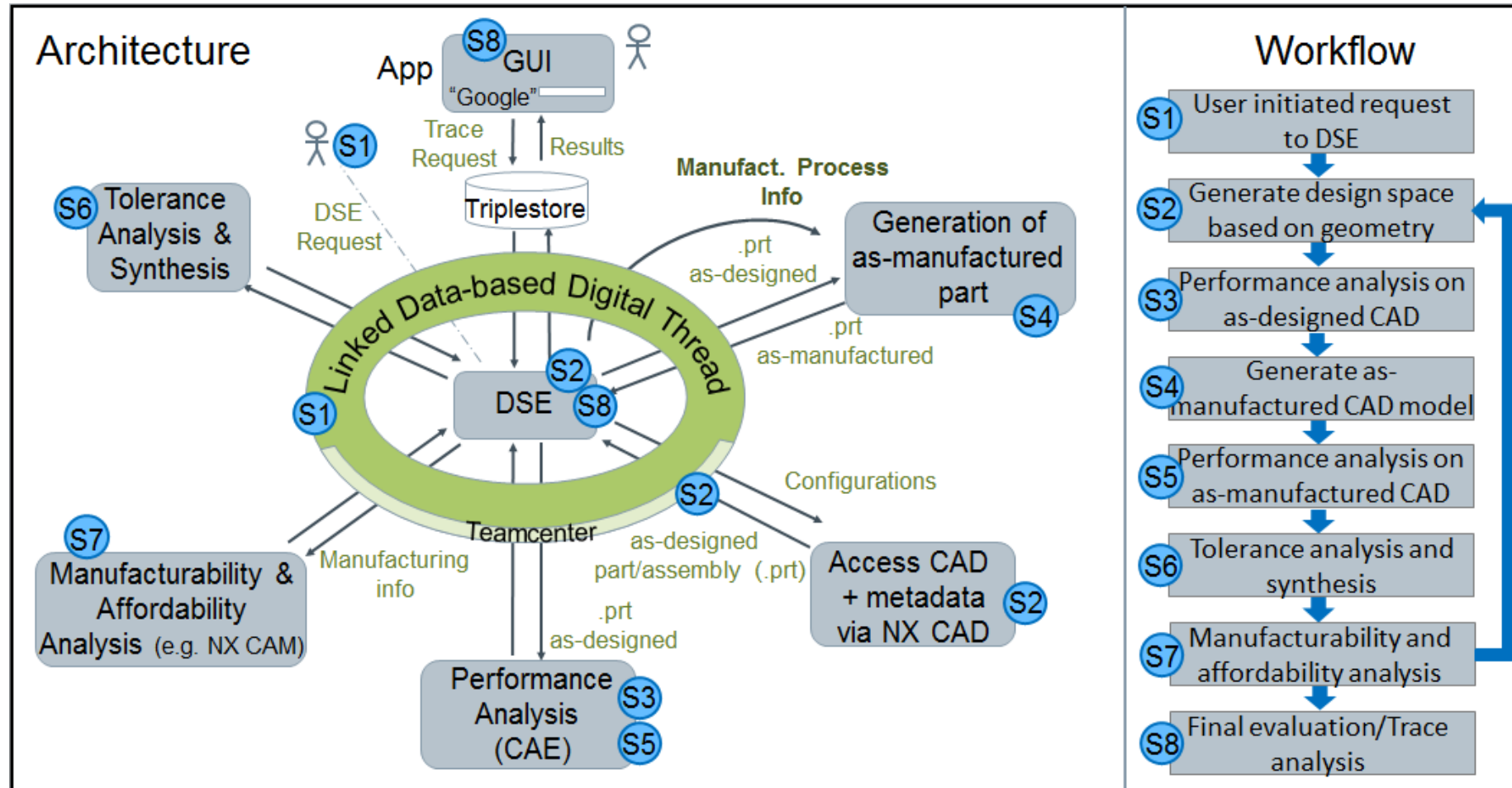
Digital Web

Extending the notion of *digital thread* to *digital web*

- Digital data and corresponding authoring and analysis tools form an interconnected network of resources and information

- Linked data: digital resources identified via URLs and linked via hyperlinks just like the WWW

   http://myCompany/myProduct/component1/cad.file

Advantages:

- Enables tool independence (think WWW): producers and consumers stick to data standards and communication protocols

- Integrate data and tools from multiple engineering disciplines
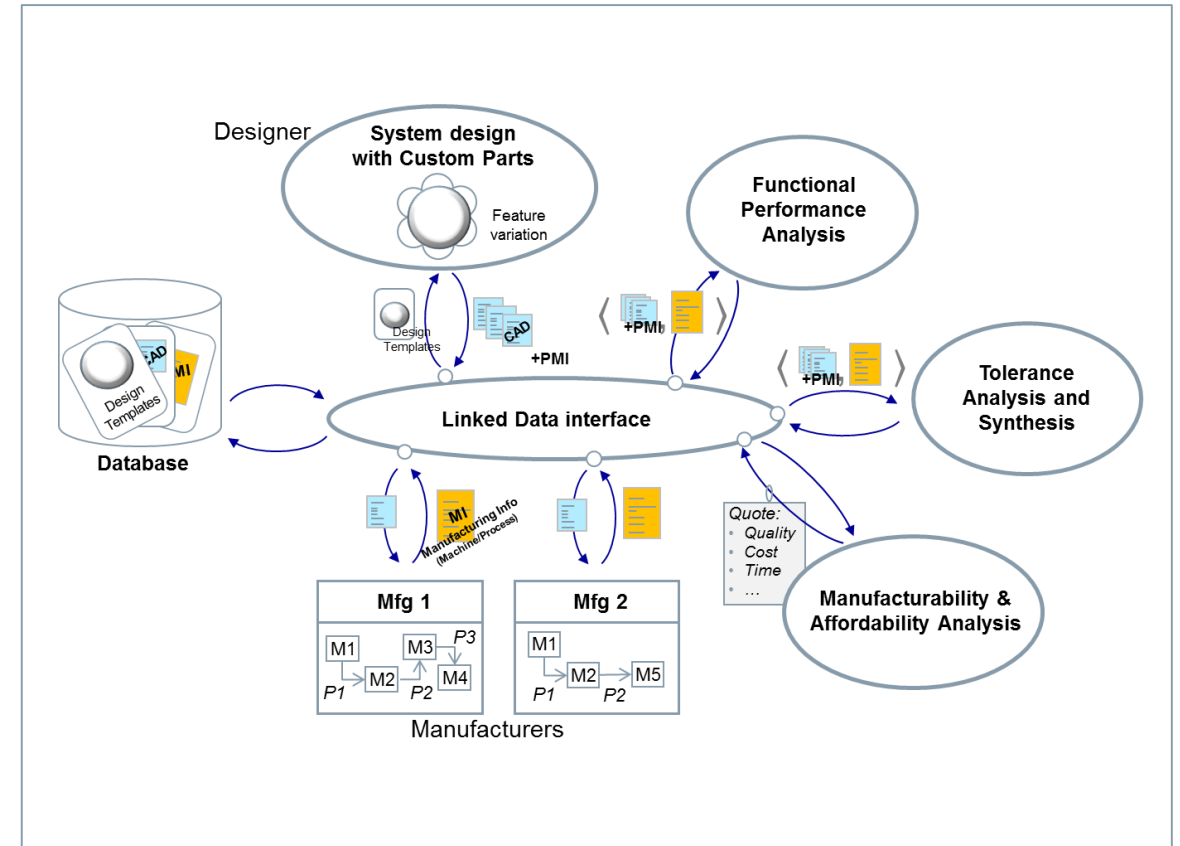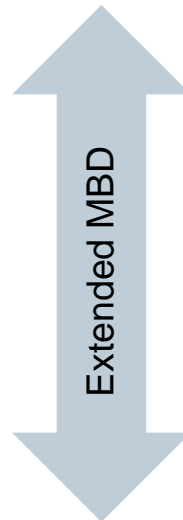
- Enables design traceability

Digital Web

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Project Overview

List of technology to be advanced and integrated

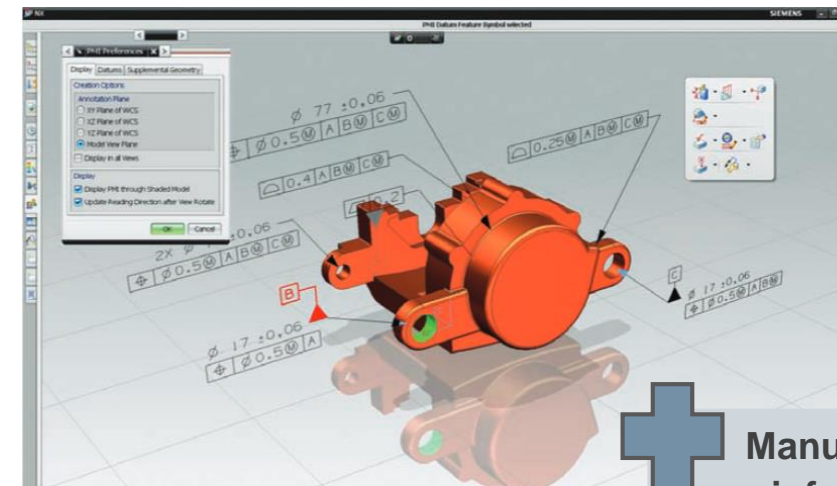- Design Space Exploration
- As-manufactured geometry creation
- Function performance analysis
- Manufacturability analysis
- Affordability analysis
- Tolerance analysis and synthesis
- Digital web development

Extended MBD

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Extended MBD

Manufacturing process information

- Identify relevant manufacturing process information such as techniques, tools, characteristics of as-manufactured geometry, costs, etc.

- Extend OpenMETA component model to include manufacturing process information

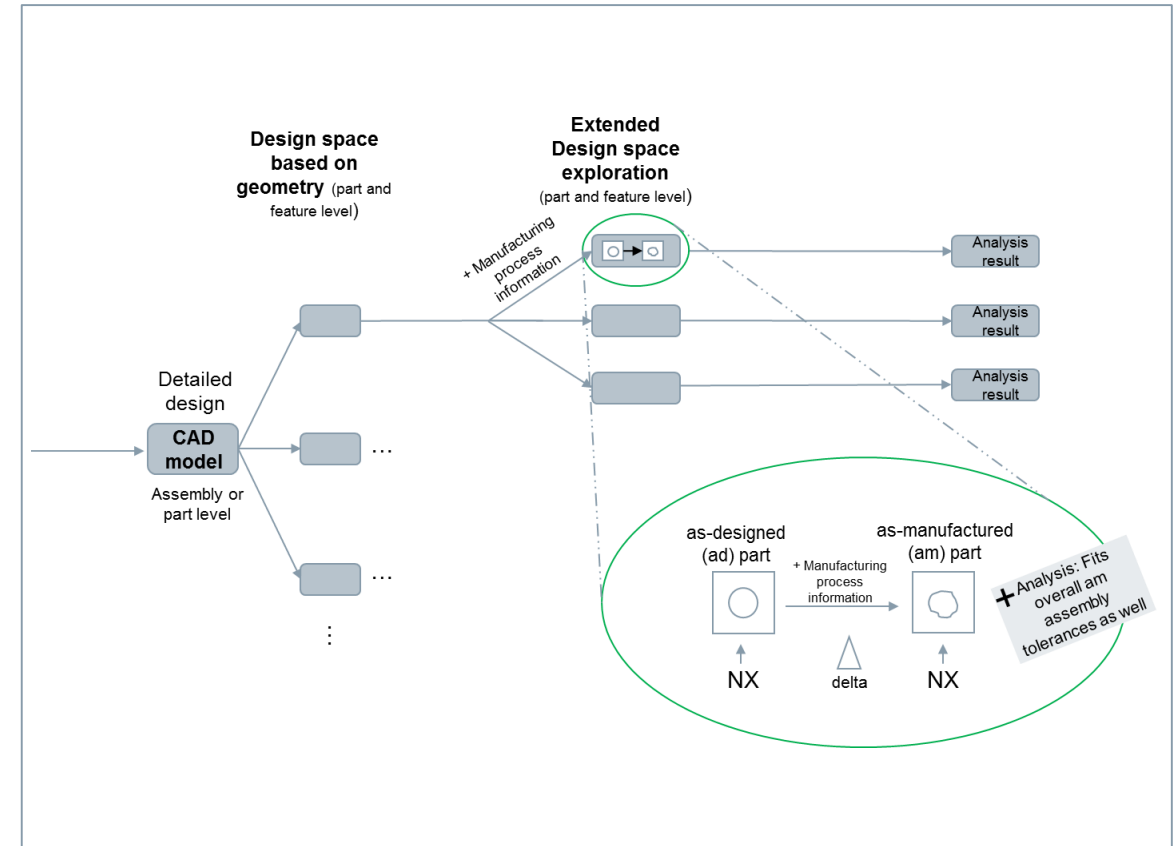- Can be links in component model (remember: digital web)

Manufacturing information

[4]

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Design Space Exploration (DSE)

Exploration of Combined Design and Manufacturing Space
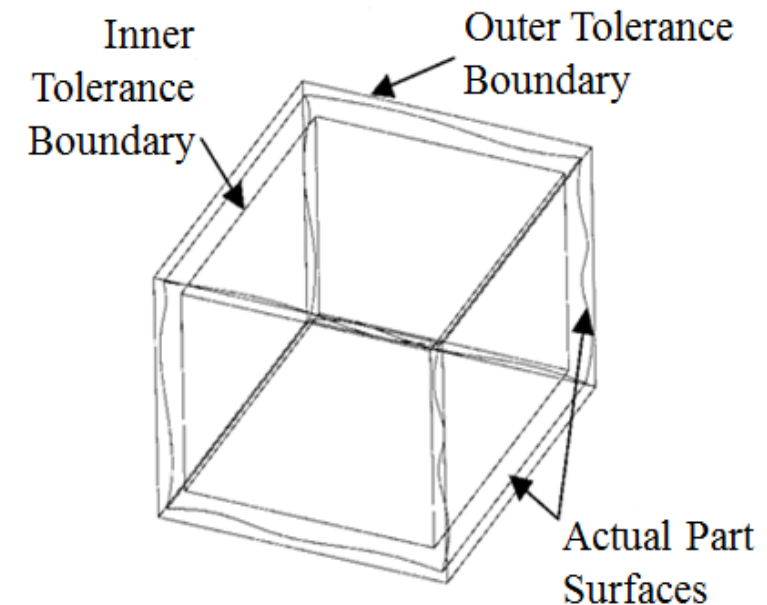
- Leverage DARPA AVM OpenMETA tools

- Extend component model and design space representation to include mfg. processes and parameters

- Include manufacturability constraints in design space exploration techniques

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As-manufactured Shape Capture

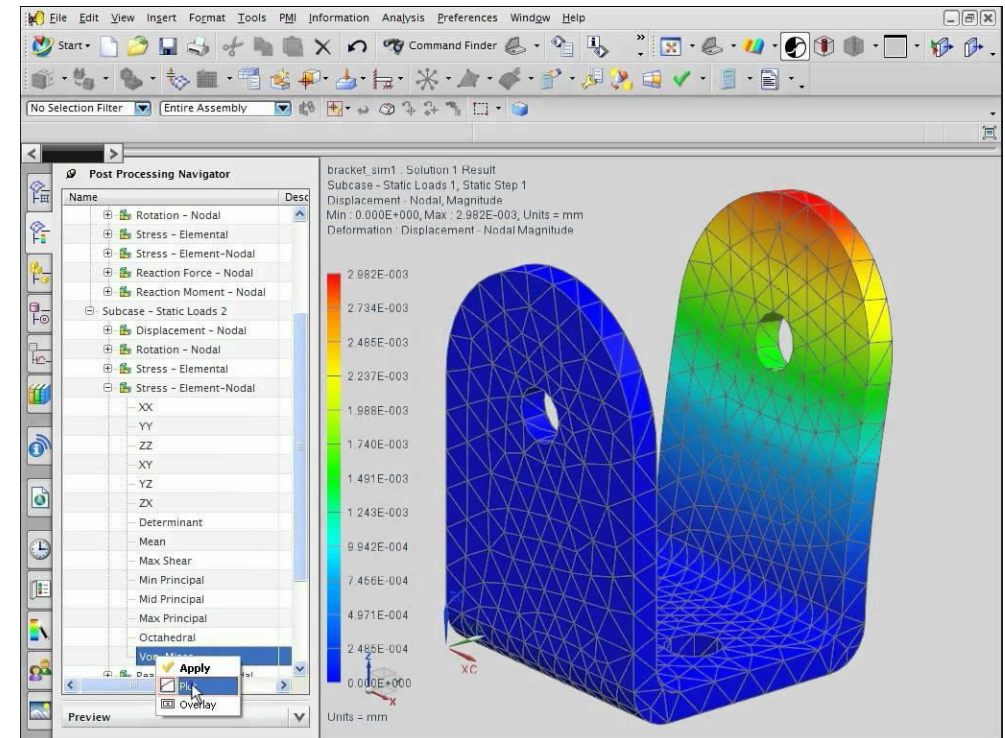## Generation of as-mfg. geometry using mfg. process info

- Replace nominal surfaces with surfaces that contain manufacturing defects introduced by different manufacturing processes

- Leverage method previously implemented using ACIS geometric modeling kernel with GIFT (Geometric modeling of imperfect forms for tolerancing)

- Extension for operating on geometry created in NX CAD system and automation of geometry conversion

Inner Tolerance Boundary

Outer Tolerance Boundary

Actual Part Surfaces

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Functional Performance Analysis

Analysis of as-designed and as-manufactured geometry

- Evaluation of functional performance on as-designed as well as as-manufactured geometry to analyze effects of manufacturing process errors

- Develop NX Open based software module for finite element analysis in NX CAE

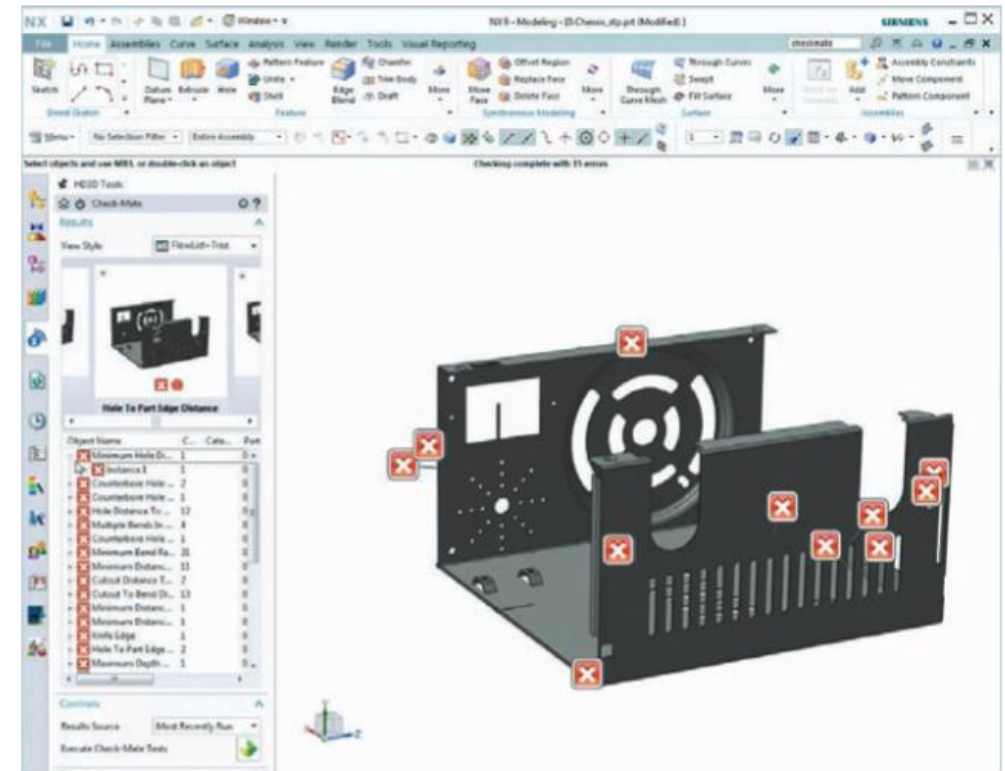- Extend GIFT tool to perform mating simulation between non-analytic surfaces

NX CAE

[5]

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Manufacturability Analysis

Checking designs for manufacturability

- Reduce manufacturing challenges and errors by avoiding designs that can cause manufacturing problems

- Leverage DFMPro for NX to evaluate manufacturability
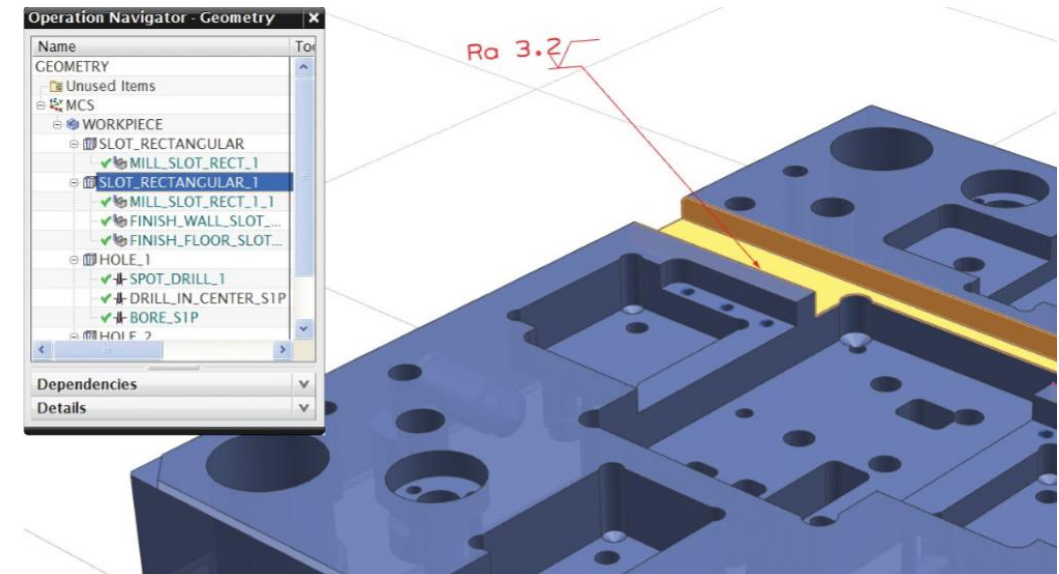
- Checks for different manufacturing operations/processes

DFMPro

[6]

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Affordability Analysis

Estimate Manufacturing Cost

- Leverage NX CAM

- Feature-based Machining approach to estimate manufacturing time and cost that also includes tolerance specifications

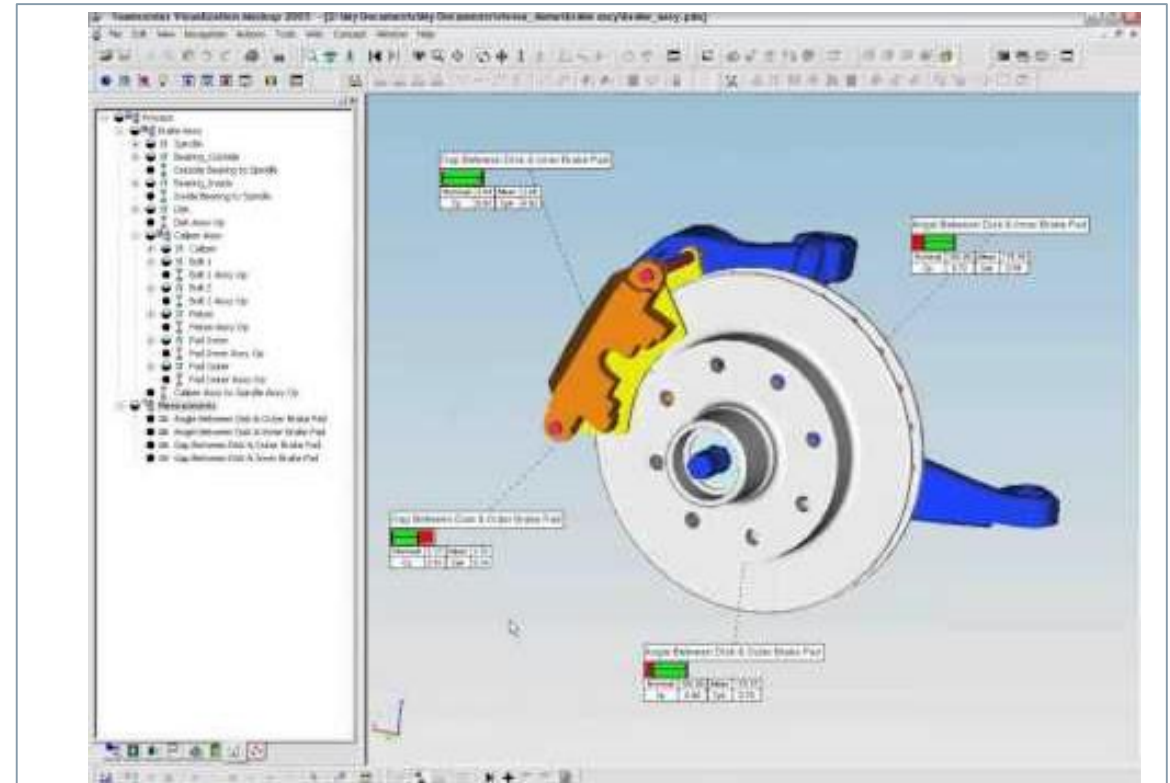- Develop NX Open based software module to automate cost estimation

NX CAM FBM

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Tolerance Analysis and Synthesis

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Stack-up analysis, clearance analysis, tolerance synthesis

- Leverage Teamcenter VSA, NX Assembly, GIFT

- Develop automated tools for tolerance stack up analysis and assembly clearance analysis

- Develop new tolerance synthesis tool that uses functional performance, manufacturability, and affordability modules
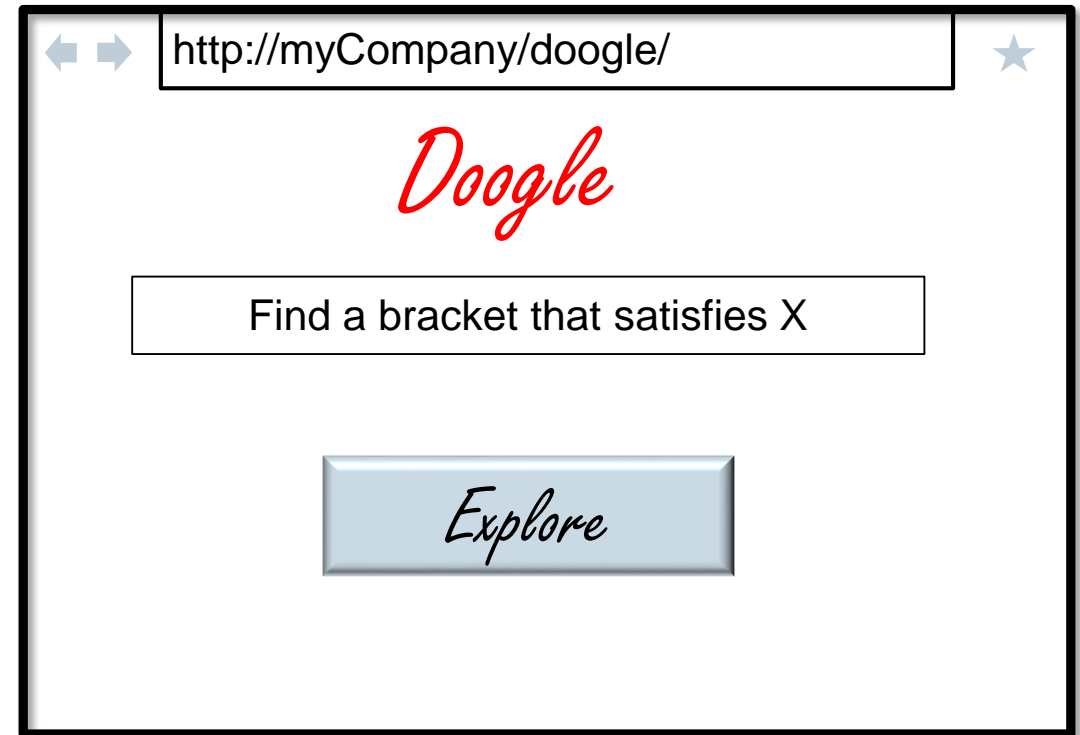

VSA

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Digital Web Development

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Linked Data based digital web and tools

- Linked data interfaces to tools including NX, Teamcenter, OpenMETA DESERT, etc.

- Linked data management solution including RDF triple store, editor, search tool, visualization tool, data import/export, etc.

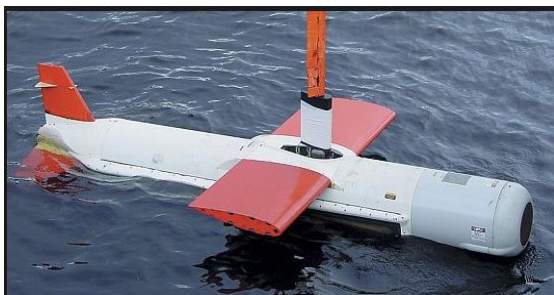- "Google" for product design and manufacturing

http://myCompany/doogle/

Doogle

Find a bracket that satisfies X

Explore

Digital Web Tool Concept

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Sample Use Cases

Validation of proposed framework prototype based on use case

Unmanned Underwater Vehicle (UUV) Hull	High Power Active Sensor Air Cooled Structure	Conformal Antenna
• Increasing need to develop low cost, light weight, durable, energy efficient UUV platforms for wide range of depths and temperatures • Focus on design and manufacture of hull structures optimized for each mission and associated environmental requirements (e.g. depth, pressure, sea currents, etc.)	• Significant design challenge for high power applications to dissipate heat as quickly as possible • Several design factors taken into account by cooling approaches (liquid or air) • Goal to minimize weight of structures and provide geometries amenable to maximizing heat transfer characteristics	• Housing of current conformal antenna structures within a radome add weight and drag and may cause structural stress to the platform • Patterns deposited directly onto, or embedded within composite fluid or aerodynamic surfaces by direct-write additive manufacturing technology as potential substitute
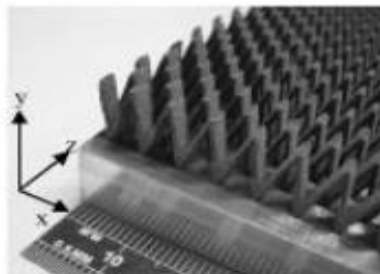
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Performance Improvement Metrics

Metric	Present State (Baseline)	Future State (Project Goal)
Quantification of the As-Designed to the As-Built (Time, Accuracy)	Part must be physically produced and compared against the original design.	Part is produced virtually according to manufacturing process and parameters. 5 times faster than manual, with improved accuracy than manual model construction.
Linked Data Linkability/Traceability (Qualitative)	Few proprietary formats can be linked using vendor-specific software, resulting in incomplete data integration.	Data can be linked regardless of their provenance with complete data integration resulting from open web standards for data.
DSE Point Designs for Manufacturability (Qualitative)	OpenMETA performs DSE on designs in as-designed spaces.	OpenMETA to perform DSE on as-manufactured spaces and on the joint design and manufacturing space.
Productivity (% reduction in cycle time, out of phase rework, system requirement variance)	• Days to Weeks cycle times • Rework across multiple phases • Manual, based on inspection	• Hours to days cycle times • In-phase rework based on model baselines • Semi-automated based on model analysis
Model-based Inspection (Number of design variants modeled)	Manual process, limited by time and budget for labor	Limited only by computing capacity
Product Customization (Number of spatial extents, number of material properties accommodated)	• Dozens of spatial extents • Small number of material properties	Limited only by computing capacity

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Project Team

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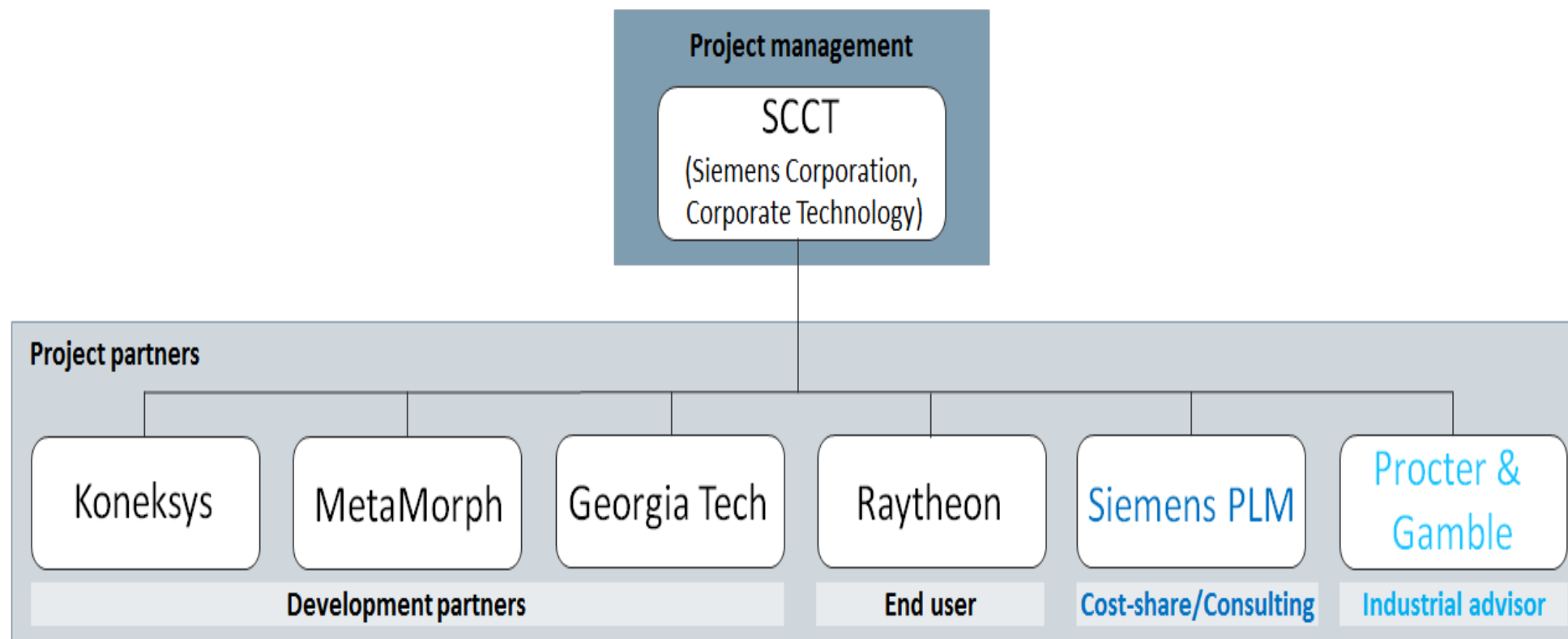
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Questions/Comments/Suggestions?

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References

[1] Pictures on Slide 2: Realizing innovation, NIST MBE Summit 2014 presentation

[2] Picture on Slide 3, left: http://manufacturingwisdom.com/tag/eating-sequence/

[3] Pictures on Slide 3, right: Realizing innovation, NIST MBE Summit 2014 presentation

[4] Picture on Slide 7: http://www.plm.automation.siemens.com/en_us/products/nx/for-design/drafting-documentation/product-manufacturing-information.shtml#lightview%26uri=tcm:1023-4581%26title=Product%20and%20Manufacturing%20Information%20%28PMI%29%20-%20NX%20Fact%20Sheet%20-%209645%26docType=pdf

[5] Picture on Slide 10: https://www.youtube.com/watch?v=2Dm01LX0buI

[6] Picture on Slide 11: https://www.plm.automation.siemens.com/en_us/products/nx/for-design/visual-analytics/design-for-manufacturing.shtml#lightview%26uri=tcm:1023-225149%26title=DFMPro-for-NX-Fact-Sheet-41078%26docType=pdf

[7] Picture on Slide 12: https://www.plm.automation.siemens.com/en_us/products/nx/for-manufacturing/cam/programming-automation.shtml#lightview%26uri=tcm:1023-4561%26title=High-Productivity-Part-Manufacturing-Brochure-24419%26docType=pdf

[8] Picture on Slide 13: https://www.plm.automation.siemens.com/en_us/products/tecnomatix/manufacturing-planning/dimensional-quality/variation-analysis.shtml

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